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TECHNICAL REPORT

Dynamic modules –
Part 6-6: Failure mode effect analysis for optical units of dynamic modules

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FOREWORD

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IEC 62343-6-6, which is a technical report, has been prepared by subcommittee 86C: Fibre optic systems and active devices, of IEC technical committee 86: Fibre optics.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
86C/944/DTR	86C/959/RVC

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of IEC 62343 series, published under the general title *Dynamic modules,* can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

DYNAMIC MODULES –

Part 6-6: Failure mode effect analysis for optical units of dynamic modules

1 Scope

This part of IEC 62343, which is a technical report, describes failure mode effect analysis (FMEA) for optical units of dynamic modules. FMEA is one of the effective and useful analysis methods to determine the reliability evaluation test items and conditions which are defined in future reliability qualification documents. In order to estimate the lifetime for a module, there is a typical procedure. The first step is to identify the dominant failure modes. The second step is to determine the acceleration tests according to these failure modes. The third step is to carry out the test. The fourth step is to estimate the acceleration factors. Finally, the fifth step is to calculate the lifetime of the dynamic module. The IEC 61300-2 series defines environment and mechanical tests. This technical report describes the dominant failure mode for dynamic modules and relevant tests from the IEC 61300-2 series.

2 Normative references

The following reference documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61300-2-1, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 2-1: Tests – Vibration (sinusoidal)*

IEC 61300-2-4, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 2-4: Tests – Fibre/cable retention*

IEC 61300-2-9, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 2-9: Tests – Shock*

IEC 61300-2-17, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 2-17: Tests – Cold*

IEC 61300-2-18, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 2-18: Tests – Dry heat – High temperature endurance*

IEC 61300-2-19, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 2-19: Tests – Damp heat (steady state)*

IEC 61300-2-22, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 2-22: Tests – Change of temperature*

IEC 61300-2-44, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 2-44: Tests – Flexing of the strain relief of fibre optic devices*

IEC 62005-3, *Reliability of fibre optic interconnecting devices and passive components – Part 3: Relevant tests for evaluating failure modes and failure mechanisms for passive components*

3 Consideration of types of dynamic modules

There are many types of dynamic modules: dynamic channel equalizer, tuneable optical chromatic dispersion compensator, dynamic gain tilt equalizer, wavelength selective switch, wavelength blocker, optical performance monitor, optical switch, and so on. The main feature of dynamic modules is to control their performances during operation. In order to achieve their features, many kinds of control mechanisms are used for dynamic modules; MEMS (micro electro mechanical system), stepping motor, electromagnet, thermo optics, magnet optics, electro optics, LCD (liquid crystal devices), and so on.

Table 1 shows the first guidance of categorization of dynamic modules to consider how to evaluate. Dynamic modules without an electrical circuit board can be considered similar to passive optical components for purposes of evaluation. On the other hand, for dynamic modules with a control circuit board, it is necessary to give special consideration. There are mainly two types of internal design for dynamic modules: those for which it is easy to divide the constituting parts to consider their reliability, and those which it is not easy to divide. It is necessary to consider how to evaluate according to these structures.

NOTE This technical report describes FMEA only for optical units for dynamic modules. It is necessary to evaluate whole dynamic modules including control circuit boards and firmware if used.

4 Typical failure points

In addition to control circuit boards and control of moving parts, a typical optical unit for a dynamic module consists of the following parts: optical element, outer package, fibre pigtails, optical semiconductor chips, and joint points of these elements. These elements have their own failure mode; for example, break for pigtails, displacement for joint points, and so on. Moreover, these elements may have their acceleration factor of degradation; for example, joint points fixed by adhesive are generally weak against high humidity, and so on. This failure mode analysis can be referred to FMEA for passive optical components (refer to IEC 62005-3).

There are special considerations for dynamic modules. The following are some examples. When a hermetic sealing structure is used, the damp heat test may be omitted because it can generally prevent humidity from entering the package. When using MEMS, operating shock and vibration tests are necessary because MEMS are sensitive to mechanical shock and vibration. When temperature control is used, the temperature cycling test is recommended because temperature control functions generally produce thermal stress. The temperature cycling test can accelerate thermal stress.

5 Failure modes and known failure mechanisms

For some dynamic modules, failure mode and effect analysis (FMEA) was carried out. Table 2 shows known failure mechanisms, failure effects, failure modes, relevant tests and IEC test document numbers for dynamic modules. If new technology and new dynamic modules become commercially available, they will be added to Table 2 in later revisions. Relevant tests are listed with the failure effect and the dominant failure mechanism. As other relevant tests or methods of failure mode excitation become known, these will also be added.

Table 1 – Categorization based on the structure and how to evaluate

Electrical circuits		How to evaluate	Examples
Without electrical circuits	N.A.	As optical component	VOA, 1x2/2x2 optical switch, DGTE
With electrical circuit	Easy to divide optical and electrical unit	As optical and electrical units individually, and as integrated dynamic module	VOA, VOA-MUX, DCDC, DCE, Matrix switch, channel monitor, performance monitor
	Difficult to divide optical and electrical unit	To evaluate as integrated dynamic module	Wavelength blocker, wavelength selectable switch
NOTE 1 Optical active and passive components should comply to the reliability qualification requirement defined in the IEC 62572 series for active components and IEC 62009-9 series for passive optical components, respectively. In cases in which it is difficult to divide optical and electrical units, integrated modules should be tested. NOTE 2 Electrical circuit boards should be qualified individually. The following standard series are useful references for the quality of electrical circuit boards: IEC 61188, IEC 61189, IEC 61190, and IEC 61191. NOTE 3 Three pieces should be tested.			

Table 2 – Failure mode and known failure mechanisms for the optical units of dynamic devices

Dynamic devices		Constitution parts	Known failure mechanisms	Failure modes	Degradation acceleration factors	Relevant tests	IEC references
Variable optical attenuators	MEMS type	MEMS	Stacking the moving part	Uncontrollable	Mechanical stress Excess driving power	Shock (storage) Vibration (storage) Maximum absolute rating test (electrical) On/off driving test	61300-2-9 61300-2-1 Under study Under study
			Distortion of hinge/mirror	Insertion loss increase Attenuation change Return loss decrease Dynamic range of attenuation decrease PDL increase WDL increase	Mechanical stress Thermal stress Excess driving power	Shock (storage) Vibration (storage) Shock and vibration (operating) Change of temperature Maximum absolute rating test On/off driving test	61300-2-9 61300-2-1 Under study 61300-2-22 Under study Under study
			Reflectance of mirror changing	Insertion loss increase Attenuation change Return loss decrease PDL increase WDL increase	High humidity (non-hermetic sealed)	Damp heat	61300-2-19
		Collimator	Dislocation of fixing points of optical parts	Insertion loss increase Attenuation change Dynamic range of attenuation decrease PDL increase WDL increase	Thermal stress High humidity (non-hermetic sealed and using adhesive) Mechanical stress	Change of temperature High temperature Damp heat Shock (storage) Vibration (storage)	61300-2-22 61300-2-18 61300-2-19 61300-2-9 61300-2-1
		Pigtail	Fibre broken, micro-bending	Insertion loss increase No operation	Mechanical stress for pigtail	Fibre cable retention Optical fibre cable flexing	61300-2-4 61300-2-44
	Liquid crystal type	LCD	Degradation of LCD	Insertion loss increase Attenuation change Return loss decrease Dynamic range of attenuation decrease PDL increase WDL increase	Thermal stress High humidity (non-hermetic sealed) Mechanical stress	Change of temperature High temperature Damp heat Shock (storage) Vibration (storage)	61300-2-22 61300-2-18 61300-2-19 61300-2-9 61300-2-1
			Electrical polarization of LCD	Uncontrollable	Excess driving power	Maximum absolute rating test On/off driving test	Under study Under study
			Freezing of LCD	Uncontrollable	Low temperature	Cold	61300-2-17
		Collimator	Same as MEMS type				
		Pigtail	Same as MEMS type				

Table 2 *(continued)*

Dynamic devices		Constitution parts	Known failure mechanisms	Failure modes	Degradation acceleration factors	Relevant tests	IEC references
Variable optical attenuators	Magnet optic type	Magnet optic part	Dislocation of magnet, Faraday rotator and birefringent crystal	Insertion loss increase Attenuation change Return loss decrease Dynamic range of attenuation decrease PDL increase WDL increase	Thermal stress High humidity (non-hermetic sealed and using adhesive) Mechanical stress	Change of temperature High temperature Damp heat Shock (storage) Vibration (storage)	61300-2-22 61300-2-18 61300-2-19 61300-2-9 61300-2-1
		Collimator					
		Pigtail	Same as MEMS type				
	Mechanical type	Moving part	Stacking the moving part	Uncontrollable	Mechanical stress High humidity (non-hermetic) Excess driving power	Shock (storage) Vibration (storage) Damp heat Maximum absolute rating test (electrical) On/off driving test	61300-2-9 61300-2-1 61300-2-19 Under study Under study
			Degradation of moving part	Driving power increase	Mechanical stress Thermal stress Excess driving power High humidity (non-hermetic sealed)	Shock (storage) Vibration (storage) Shock and vibration (operating) Change of temperature Maximum absolute rating test On/off driving test Damp heat	61300-2-9 61300-2-1 Under study 61300-2-22 Under study Under study 61300-2-19
			Distortion of mirror	Insertion loss increase Return loss decrease Crosstalk increase PDL increase	Mechanical stress Thermal stress Excess driving power	Shock (storage) Vibration (storage) Change of temperature Maximum absolute rating test On/off driving test	61300-2-9 61300-2-1 61300-2-22 Under study Under study
			Reflectance of mirror changing	Insertion loss increase Attenuation change Return loss decrease PDL increase WDL increase	High humidity (non-hermetic sealed)	Damp heat	61300-2-19
		Collimator	Same as MEMS type				
		Pigtail	Same as MEMS type				

Table 2 *(continued)*

Dynamic devices		Constitution parts	Known failure mechanisms	Failure modes	Degradation acceleration factors	Relevant tests	IEC references
Variable optical attenuators	Planar waveguide type (thermal optic effect)	Waveguide	Refractive index changing	Insertion loss increase Attenuation change Return loss decrease Dynamic range of attenuation decrease PDL increase	Thermal stress High humidity (non-hermetic sealed and using adhesive) Mechanical stress	Change of temperature High temperature Damp heat Shock (storage) Vibration (storage)	61300-2-22 61300-2-18 61300-2-19 61300-2-9 61300-2-1
			Electrode degradation	Dynamic range of attenuation decrease	High humidity (non-hermetic sealed and using adhesive) Excess driving power	Damp heat Maximum absolute rating test Diving test	61300-2-19 Under study Under study
		Fixing point between waveguide and fibres	Dislocation by the degradation of adhesive	Insertion loss increase	Thermal stress High humidity (non-hermetic sealed and using adhesive)	Change of temperature Damp heat	61300-2-22 61300-2-19
		Pigtail	Same as MEMS type				

Table 2 *(continued)*

Dynamic devices		Constitution parts	Known failure mechanisms	Failure modes	Degradation acceleration factors	Relevant tests	IEC references
Optical switches	Mechanical type	Moving part	Stacking the moving part	Uncontrollable	Same as VOA mechanical type		
			Degradation of moving part	Driving power increase Switching time increase	Same as VOA mechanical type		
			Distortion of mirror	Insertion loss increase Return loss decrease Crosstalk increase PDL increase	Same as VOA mechanical type		
			Reflectance of mirror changing	Insertion loss increase Return loss decrease PDL increase WDL increase	Same as VOA mechanical type		
		Collimator	Same as VOA MEMS type	Insertion loss increase Crosstalk increase PDL increase WDL increase	Same as VOA mechanical type		
		Pigtail	Same as VOA MEMS type				
	Planar waveguide type (thermal optic effect)	Waveguide	Refractive index changing	Insertion loss increase Crosstalk increase Return loss decrease PDL increase	Same as VOA PLC TO type		
			Electrode degradation	Crosstalk increase	Same as VOA PLC TO type		
		Fixing point between waveguide and fibres	Dislocation by the degradation of adhesive	Insertion loss increase	Same as VOA PLC TO type		
		Pigtail	Same as VOA MEMS type				

Table 2 *(continued)*

Dynamic devices		Constitution parts	Known failure mechanisms	Failure modes	Degradation acceleration factors	Relevant tests	IEC references
Optical switches	MEMS type	MEMS	Stacking the moving part	Uncontrollable	Same as VOA MEMS type		
			Distortion of hinge/mirror	Insertion loss increase Crosstalk increase Return loss decrease PDL increase WDL increase	Same as VOA MEMS type		
			Reflectance of mirror changing	Insertion loss increase Crosstalk increase Return loss decrease PDL increase WDL increase	Same as VOA MEMS type		
		Collimator	Same as VOA MEMS type	Same as VOA MEMS type except; Crosstalk increase instead of Attenuation change	Same as VOA MEMS type		
		Pigtail	Same as VOA MEMS type				
	Electrical optics type (LN)	Waveguide	Refractive index changing	Insertion loss increase Crosstalk increase Driving voltage changing	Thermal stress Mechanical stress Excess driving power	Change of temperature High temperature Damp heat Shock (storage) Vibration (storage) Maximum absolute rating test Diving test	61300-2-22 61300-2-18 61300-2-19 61300-2-9 61300-2-1 Under study Under study
			Electrode degradation	Crosstalk increase	Same as switch PLC TO (VOA PLC TO) type		
		Fixing point between waveguide and fibres	Dislocation by the degradation of adhesive	Insertion loss increase	Same as switch PLC TO (VOA PLC TO) type		
		Pigtail	Same as VOA MEMS type				

Table 2 *(continued)*

Dynamic devices		Constitution parts	Known failure mechanisms	Failure modes	Degradation acceleration factors	Relevant tests	IEC references
Tunable filters (electrical control)	MEMS etalon type	MEMS	Stacking the moving part	Uncontrollable	Same as VOA MEMS type		
			Distortion of hinge/mirror	Insertion loss increase Centre-wavelength change Return loss decrease PDL increase FWHM increase Tunable wavelength range decrease	Same as VOA MEMS type		
			Reflectance of etalon mirror changing	Insertion loss increase Centre-wavelength change Return loss decrease PDL increase FWHM increase	Same as VOA MEMS type		
		Collimator	Same as VOA MEMS type	Insertion loss increase Centre-wavelength change Return loss decrease PDL increase FWHM increase Tunable wavelength range decrease	Same as VOA MEMS type		
		Pigtail	Same as VOA MEMS type				
	PZT etalon type	PZT	PZT degradation	Driving voltage increase	High humidity Thermal stress Excess driving	Damp heat Change of temperature Maximum absolute rating test On/off driving test	61300-2-19 61300-2-22 Under study Under study
		Etalon mirror	Reflectance of etalon mirror changing	Insertion loss increase Centre-wavelength change Return loss decrease PDL increase FWHM increase	Same as VOA MEMS type		
		Optical part and collimator	Dislocation of fixing points of optical parts	Insertion loss increase Centre-wavelength change FWHM increase Tunable wavelength range decrease	Thermal stress High humidity (non-hermetic sealed and using adhesive) Mechanical stress	Change of temperature High temperature Damp heat Shock (storage) Vibration (storage)	61300-2-22 61300-2-18 61300-2-19 61300-2-9 61300-2-1
		Pigtail	Same as VOA MEMS type				

Table 2 *(continued)*

Dynamic devices		Constitution parts	Known failure mechanisms	Failure modes	Degradation acceleration factors	Relevant tests	IEC references
Tunable filters (electrical control)	Thin film filter mechanical control type	Moving part	Stacking the moving part	Uncontrollable	Same as VOA mechanical type		
			Degradation of moving part	Driving power increase	Same as VOA mechanical type		
			Thin film filter degradation	Insertion loss increase Centre-wavelength change FWHM increase	High humidity (non-hermetic sealed)	Damp heat	61300-2-19
		Collimator	Same as VOA MEMS type	Insertion loss increase Centre-wavelength change Return loss decrease PDL increase FWHM increase Tunable wavelength range decrease	Same as VOA MEMS type		
		Pigtail	Same as VOA MEMS type				

Table 2 *(continued)*

Dynamic devices		Constitution parts	Known failure mechanisms	Failure modes	Degradation acceleration factors	Relevant tests	IEC references
Dynamic chromatic dispersion compensators	VIPA type	Moving part	Degradation of stepping motor	Uncontrollable Dynamic range of CD decrease	Thermal stress Mechanical stress Excess driving High humidity (non-hermetic)	Shock (storage) Vibration (storage) Shock and vibration (operating) Change of temperature Maximum absolute rating test On/off driving test Damp heat	61300-2-9 61300-2-1 Understudy 61300-2-22 Under study Under study 61300-2-19
		VIPA mirror	Distortion of VIPA mirror	Centre-wavelength change Insertion loss increase GDR increase	Thermal stress High humidity (non-hermetic) Mechanical stress	Change of temperature Damp heat High temperature Shock (storage) Vibration (storage)	61300-2-22 61300-2-19 61300-2-18 61300-2-9 61300-2-1
			Temperature uncontrollable	Centre-wavelength change Insertion loss increase	Thermal stress High humidity (non-hermetic) Mechanical stress	Change of temperature Damp heat High temperature Shock (storage) Vibration (storage)	61300-2-22 61300-2-19 61300-2-18 61300-2-9 61300-2-1
		Optical parts and collimator	Dislocation of fixing points of optical parts (3D mirror distortion)	Insertion loss increase Centre-wavelength change Dynamic range of DC decrease GDR increase	Thermal stress High humidity (non-hermetic sealed and using adhesive) Mechanical stress	Change of temperature Damp heat High temperature Shock (storage) Vibration (storage)	61300-2-22 61300-2-19 61300-2-18 61300-2-9 61300-2-1
		Pigtail	Same as VOA MEMS type				

Table 2 *(continued)*

Dynamic devices		Constitution parts	Known failure mechanisms	Failure modes	Degradation acceleration factors	Relevant tests	IEC references
Dynamic chromatic dispersion compensators	FBG thermal control type	Thermal control part	TEC/heater degradation	Insertion loss increase Wavelength range change Dynamic range of CD decrease	Thermal stress High humidity (non-hermetic) Mechanical stress Excess driving	Change of temperature Damp heat High temperature Shock (storage) Vibration (storage) Maximum absolute rating test On/off driving test	61300-2-22 61300-2-19 61300-2-18 61300-2-9 61300-2-1 Understudy Under study
		Fixing point between FBG and temperature control	Fibre bending	Insertion loss increase Wavelength range change CD changing GDR increase	Thermal stress High humidity (non-hermetic) Mechanical stress	Change of temperature Damp heat Shock (storage) Vibration (storage)	61300-2-22 61300-2-19 61300-2-9 61300-2-1
		FBG	Refractive index changing	CD changing	High temperature	High temperature	61300-2-18
		Pigtail	Same as VOA MEMS type				

Table 2 *(continued)*

Dynamic devices		Constitution parts	Known failure mechanisms	Failure modes	Degradation acceleration factors	Relevant tests	IEC references
Dynamic gain tilt equalizers	Magnet optic type	Magnet optic part	Dislocation of magnet, Faraday rotator and birefringent crystal	Insertion loss increase Tilt change Return loss decrease PDL increase WDL increase	Same as VOA MO type		
		Collimator	Same as VOA MEMS type	Insertion loss increase Tilt change Return loss decrease PDL increase WDL increase	Same as VOA MEMS type		
		Pigtail	Same as VOA MEMS type				
	Planar waveguide type	Waveguide	Refractive index changing	Insertion loss increase Tilt change Return loss decrease PDL increase WDL increase	Same as VOA PLC TO type		
			Electrode degradation	Dynamic range of tilt change	Same as VOA PLC TO type		
		Fixing point between waveguide and fibres	Dislocation by the degradation of adhesive	Insertion loss increase	Same as VOA PLC TO type		
		Pigtail	Same as VOA MEMS type				

Table 2 *(continued)*

Dynamic devices		Constitution parts	Known failure mechanisms	Failure modes	Degradation acceleration factors	Relevant tests	IEC references
Dynamic channel equalizers	MEMS and diffractive grating type	MEMS	Stacking the moving part	Uncontrollable	Same as VOA MEMS type		
			Distortion of hinge/mirror	Insertion loss increase Attenuation change Return loss decrease Dynamic range of attenuation decrease PDL increase WDL increase	Same as VOA MEMS type		
			Reflectance of mirror changing	Insertion loss increase Attenuation change Return loss decrease PDL increase WDL increase	Same as VOA MEMS type		
		Diffractive grating, lens, prism and Collimator	Dislocation of fixing points of optical parts	Insertion loss increase Attenuation change Return loss decrease Dynamic range of attenuation decrease PDL increase WDL increase	Thermal stress High humidity (non-hermetic sealed and using adhesive) Mechanical stress	Change of temperature High temperature Damp heat Shock (storage) Vibration (storage)	61300-2-22 61300-2-18 61300-2-19 61300-2-9 61300-2-1
		Pigtail	Same as VOA MEMS type				
	Liquid crystal and diffractive grating type	LCD	Degradation of LCD	Insertion loss increase Attenuation change Return loss decrease Dynamic range of attenuation decrease PDL increase WDL increase	Same as VOA LCD type		
			Electrical polarization of LCD	Uncontrollable	Same as VOA LCD type		
			Freezing of LCD	Uncontrollable	Same as VOA LCD type		
		Diffractive grating, lens, prism and Collimator	Dislocation of fixing points of optical parts	Insertion loss increase Attenuation change Return loss decrease Dynamic range of attenuation decrease PDL increase WDL increase	Same as DCE MEMS type		
		Pigtail	Same as VOA MEMS type				

Table 2 *(continued)*

Dynamic devices		Constitution parts	Known failure mechanisms	Failure modes	Degradation acceleration factors	Relevant tests	IEC references
Wavelength blockers	MEMS and diffractive grating type	MEMS	Stacking the moving part	Uncontrollable	Same as VOA MEMS type		
			Distortion of hinge/mirror	Insertion loss increase Attenuation change Return loss decrease Dynamic range of attenuation decrease PDL increase WDL increase	Same as VOA MEMS type		
			Reflectance of mirror changing	Insertion loss increase Attenuation change Return loss decrease PDL increase WDL increase	Same as VOA MEMS type		
		Diffractive grating, lens, prism and Collimator	Dislocation of fixing points of optical parts	Insertion loss increase Attenuation change Return loss decrease Dynamic range of attenuation decrease PDL increase WDL increase	Same as DCE MEMS type		
		Pigtail	Same as VOA MEMS type				
	Liquid crystal and diffractive grating type	LCD	Degradation of LCD	Insertion loss increase Attenuation change Return loss decrease Dynamic range of attenuation decrease PDL increase WDL increase	Same as VOA LCD type		
			Electrical polarization of LCD	Uncontrollable	Same as VOA LCD type		
			Freezing of LCD	Uncontrollable	Same as VOA LCD type		
		Diffractive grating, lens, prism and Collimator	Dislocation of fixing points of optical parts	Insertion loss increase Attenuation change Return loss decrease Dynamic range of attenuation decrease PDL increase WDL increase	Same as DCE MEMS type		
		Pigtail	Same as VOA MEMS type				

Table 2 *(continued)*

Dynamic devices		Constitution parts	Known failure mechanisms	Failure modes	Degradation acceleration factors	Relevant tests	IEC references
Wavelength selectable switches	MEMS and diffractive grating type	MEMS	Stacking the moving part	Uncontrollable	Same as VOA MEMS type		
			Distortion of hinge/mirror	Insertion loss increase Attenuation change Return loss decrease Dynamic range of attenuation decrease PDL increase WDL increase	Same as VOA MEMS type		
			Reflectance of mirror changing	Insertion loss increase Attenuation change Return loss decrease PDL increase WDL increase	Same as VOA MEMS type		
		Diffractive grating, lens, prism and Collimator	Dislocation of fixing points of optical parts	Insertion loss increase Attenuation change Return loss decrease Dynamic range of attenuation decrease PDL increase WDL increase	Same as DCE MEMS type		
		Pigtail	Same as VOA MEMS type				
	Liquid crystal and diffractive grating type	LCD	Degradation of LCD	Insertion loss increase Attenuation change Return loss decrease Dynamic range of attenuation decrease PDL increase WDL increase	Same as VOA LCD type		
			Electrical polarization of LCD	Uncontrollable	Same as VOA LCD type		
			Freezing of LCD	Uncontrollable	Same as VOA LCD type		
		Diffractive grating, lens, prism and Collimator	Dislocation of fixing points of optical parts	Insertion loss increase Attenuation change Return loss decrease Dynamic range of attenuation decrease PDL increase WDL increase	Same as DCE MEMS type		
		Pigtail	Same as VOA MEMS type				

Table 2 *(continued)*

Dynamic devices		Constitution parts	Known failure mechanisms	Failure modes	Degradation acceleration factors	Relevant tests	IEC references
Wavelength selectable switches	Planar waveguide type (thermal optic effect)	Waveguide	Refractive index changing	Insertion loss increase Crosstalk increase Return loss decrease PDL increase	Same as VOA PLC TO type		
			Electrode degradation	Crosstalk increase	Same as VOA PLC TO type		
		Fixing point between waveguide and fibres	Dislocation by the degradation of adhesive	Insertion loss increase	Same as VOA PLC TO type		
		Pigtail	Same as VOA MEMS type				

Table 2 *(continued)*

Dynamic devices		Constitution parts	Known failure mechanisms	Failure modes	Degradation acceleration factors	Relevant tests	IEC references
Wavelength selectable switches	Planar waveguide and MEMS type	MEMS	Stacking the moving part	Uncontrollable	Same as VOA MEMS type		
			Distortion of hinge/mirror	Insertion loss increase Isolation decrease Return loss decrease PDL increase WDL increase	Same as VOA MEMS type		
			Reflectance of mirror changing	Insertion loss increase Isolation decrease Return loss decrease PDL increase WDL increase	Same as VOA MEMS type		
		Waveguide	Refractive index changing	Insertion loss increase Attenuation change Isolation decrease Return loss decrease PDL increase WDL increase	Same as VOA PLC TO type		
		Fixing point between waveguide and fibres	Dislocation by the degradation of adhesive	Insertion loss increase	Same as VOA PLC TO type		
		Fixing point of MEMS, lens and mirror	Dislocation of fixing points of optical parts	Insertion loss increase Attenuation change Isolation decrease Return loss decrease Dynamic range of attenuation decrease PDL increase WDL increase	Thermal stress High humidity (non-hermetic sealed and using adhesive) Mechanical stress	Change of temperature High temperature Damp heat Shock (storage) Vibration (storage)	61300-2-22 61300-2-18 61300-2-19 61300-2-9 61300-2-1
		Pigtail	Same as VOA MEMS type				

Table 2 *(continued)*

Dynamic devices		Constitution parts	Known failure mechanisms	Failure modes	Degradation acceleration factors	Relevant tests	IEC references
Channel monitors (Performance monitors)	MEMS tunable filters and PD type	MEMS	Stacking the moving part	Uncontrollable	Same as VOA MEMS type		
			Distortion of hinge/mirror	Wavelength deviation Wavelength dynamic range change	Same as VOA MEMS type		
			Reflectance of mirror changing	PD current decrease (Error increase)	Same as VOA MEMS type		
		PD	PD degradation	PD dark current increase	Electrical surge High temperature Excess driving	ESD High temperature Maximum absolute rating test	61300-2-28 Under study
		Collimator	Dislocation of fixing points of optical parts	PD current decrease (Error increase) Return loss decrease	Same as VOA MEMS type		
		Pigtail	Same as VOA MEMS type				
	Thermal tunable filter and PD type	Thermal tunable filter	Filter refractive index change	Wavelength deviation Wavelength dynamic range change	High temperature Excess driving	High temperature Maximum absolute rating test Driving test	61300-2-18 Under study Under study
			Electrode degradation	Wavelength dynamic range change	Electrical surge High temperature Excess driving	ESD High temperature Maximum absolute rating test	Under study 61300-2-28 Under study
			Transmittance of tunable filter decreasing (loss increasing)	PD current decrease (Error increase)	High temperature Excess driving	High temperature Maximum absolute rating test Driving test	61300-2-18 Under study Under study
		PD	PD degradation	PD dark current increase	Same as channel monitor MEMS type		
		Collimator	Dislocation of fixing points of optical parts	PD current decrease (Error increase) Return loss decrease	Same as VOA MEMS type		
		Pigtail	Same as VOA MEMS type				

Table 2 *(continued)*

Dynamic devices		Constitution parts	Known failure mechanisms	Failure modes	Degradation acceleration factors	Relevant tests	IEC references
Channel monitors (Performance monitors)	Planar waveguide and PD array type	Waveguide	Refractive index changing	Insertion loss increase Tilt change Return loss decrease PDL increase WDL increase	Same as VOA PLC TO type		
		Fixing point between waveguide and fibres	Dislocation by the degradation of adhesive	Insertion loss increase	Same as VOA PLC TO type		
		PD array	PD degradation	PD dark current increase (Error increase)	Electrical surge High temperature Excess driving	ESD High temperature Maximum absolute rating test	Under study 61300-2-28 Under study
		PD fixing point	Dislocation of fixing points of PD array	PD current decrease (Error increase)	Thermal stress High humidity (non-hermetic sealed and using adhesive) Mechanical stress	Change of temperature High temperature Damp heat Shock (storage) Vibration (storage)	61300-2-22 61300-2-18 61300-2-19 61300-2-9 61300-2-1
		Pigtail	Same as VOA MEMS type				

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